E3 RESTORE Storage Revenue Forecasting and CAISO Storage Views

Webinar Presentation

July 17, 2024

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Energy+Environmental Economics

Agenda

+ Introduction to E3
+ CAISO Storage Market Trends
+ E3 RESTORE Storage Revenue Methodology Overview
+ Key Takeaways
+ Q&A

Introduction to E3

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Who is E3?

Thought Leadership, Fact Based, Trusted.

130+ full-time consultants

30+ years of deep expertise

Engineering, Economics, Mathematics, and Public Policy Degrees


San Francisco


New York

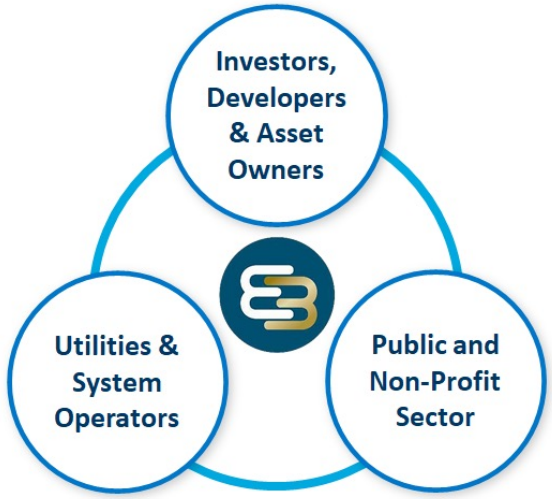

Boston


Calgary


Denver

E3 Clients

300+ projects per year across our diverse client base



Recent Examples of E3 Projects

Buy-side diligence support on several successful investments in electric utilities (>$15B in total)

Supporting investment in several stand-alone energy storage platforms and individual assets across North America (15+ GW | >$5B)

Acquisition support for several portfolios and individual gas-fired and renewable generation assets (20+ GW | >$10B)

Strategic support for many project developers and investors especially on data center topics

Strategic advisory support for a SPAC offering of a distributed energy resource aggregation software company (~$1.3B)

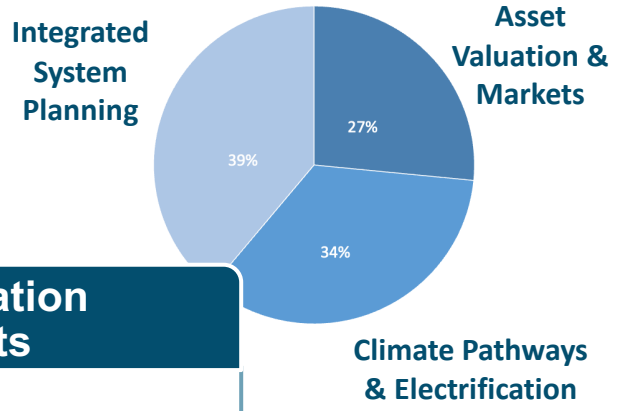
Supporting an investment into an electric vehicle V2G software company (~$750M)

Buy-side diligence support to acquire several residential and C&I solar portfolios (>2+ GW |200,000+ customers)

Supporting investment in over 5+ GW of community solar and distributed energy resource projects

E3's 3 Practice Areas

+ E3 has organized itself across three main practice areas to maximize its impact through the diversity of clients, project work, and technical innovation to support the energy transition across North America in a holistic, transparent, and intellectually honest manner



Climate Pathways & Electrification

- Climate pathways studies
- Future of gas
- Low carbon fuels
- Building electrification
- Transportation electrification
- Load forecasting

Integrated System Planning

- Integrated system planning for electricity: G, T, & D & non-wires alternatives
- Utility procurement
- Rate design
- Grid modernization
- Avoided costs
- Distributed resource planning

Asset Valuation & Markets

- Asset valuation and due diligence
- Strategic advisory for commercial clients
- Energy market price forecasting
- Market design & analysis
- DER dispatch & asset optimization

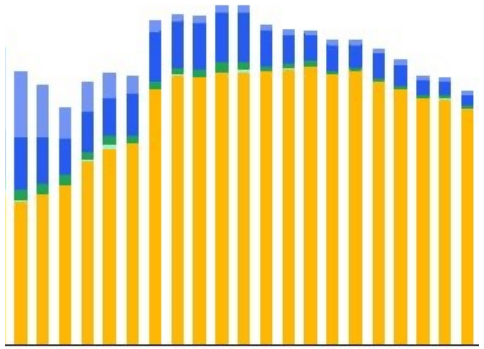
Policy — Integrated Energy Planning — Commercial Interests

E3's Work on Storage

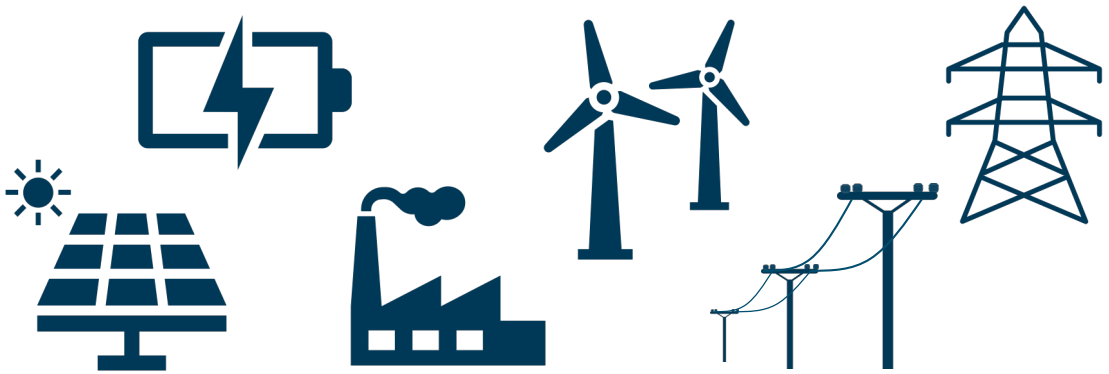
Revenue Forecasting & Advisory Support

Market Price + Asset Revenue Forecasts

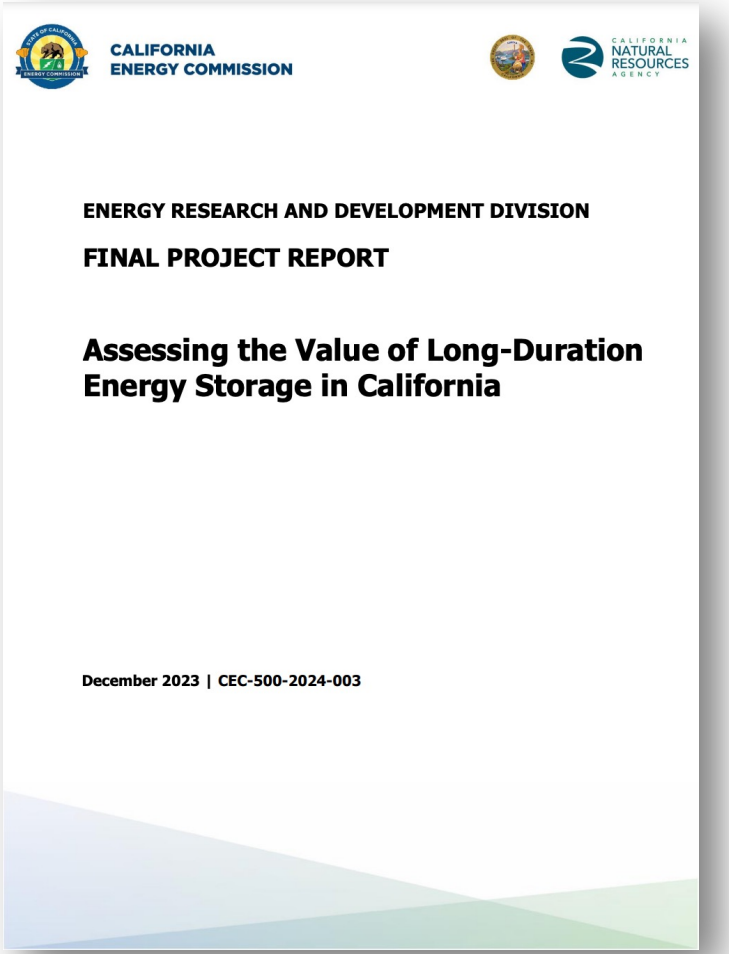
- Battery Storage Revenues
- Hub Prices
- AS Products
- Nodal LMPs
- RA Prices, RECs



Project Development, Due Diligence, Strategy



Public Studies



New York 2022 Energy Storage Roadmap

Massachusetts Report *Charging Forward: Energy Storage in a Net Zero Commonwealth*

CAISO Storage Market Trends

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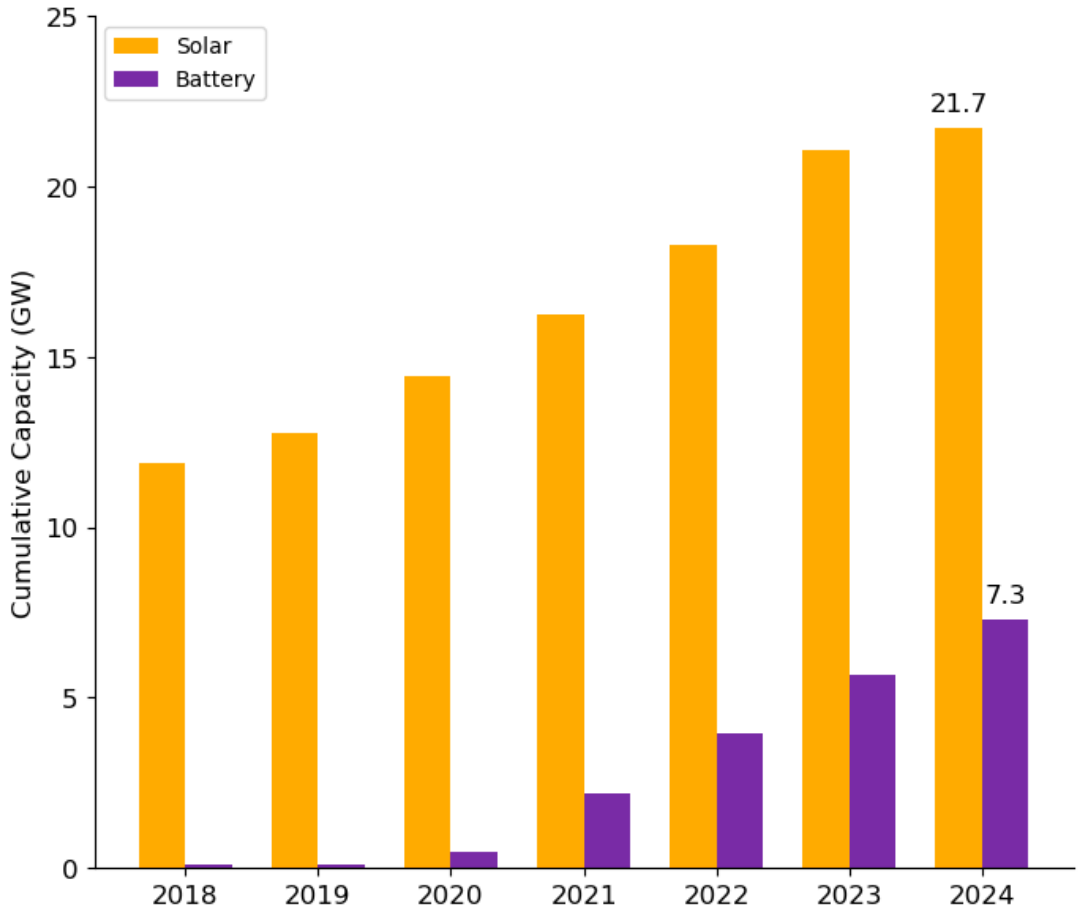
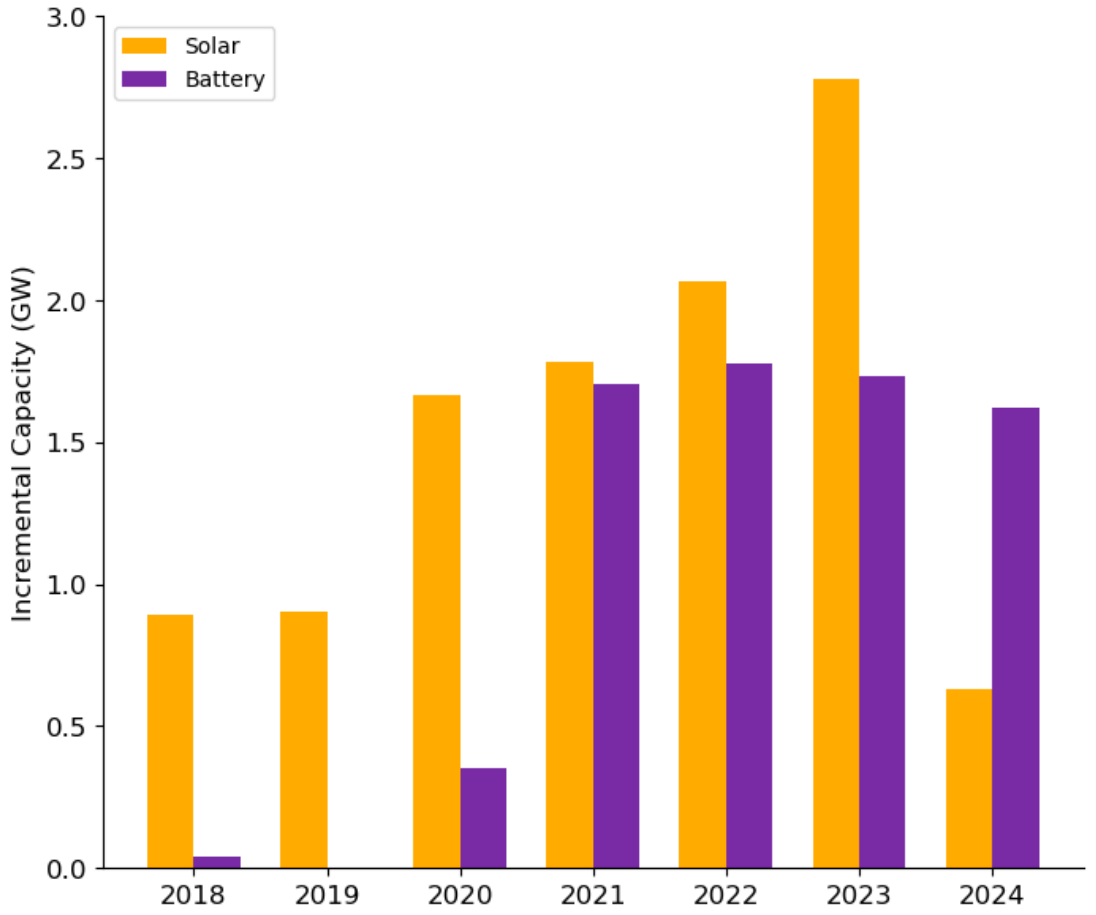
CAISO Solar and Storage Builds Have Increased Significantly Since 2018

Cumulative Capacity (GW)

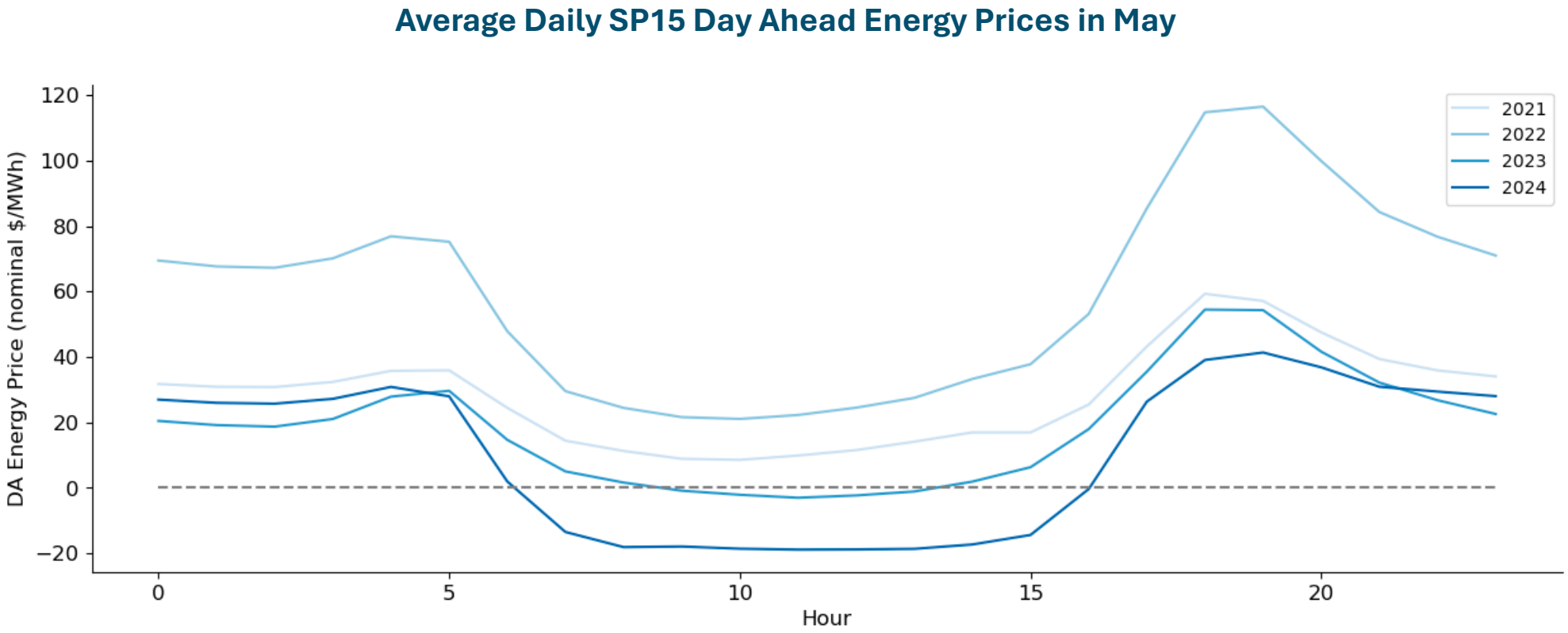


Incremental Capacity (GW)

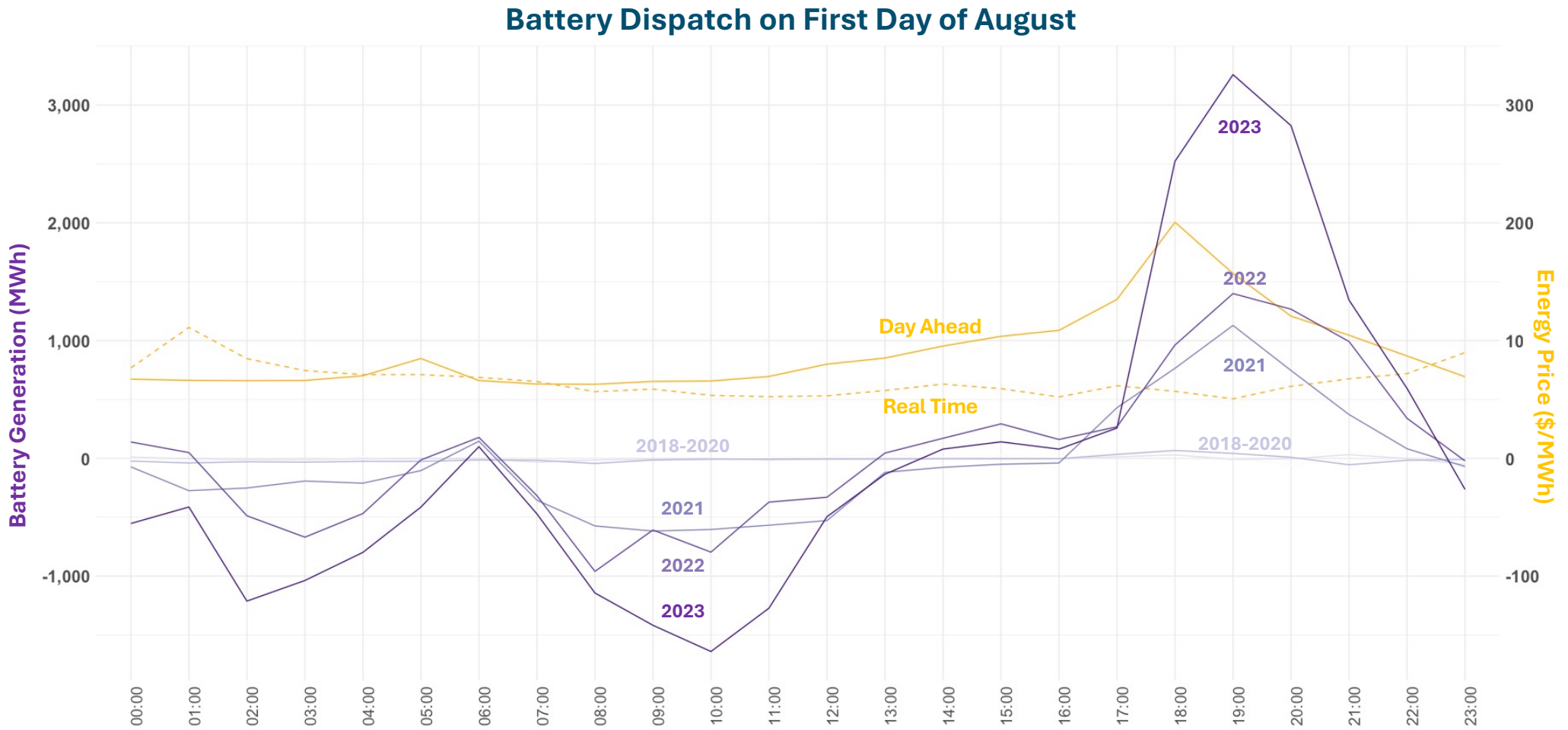


Note: Data provided through June 30th, 2024

Solar Resources Continue to Depress Mid-day Energy Prices, with Increasing Frequency and Depth of Negative Prices in the Spring

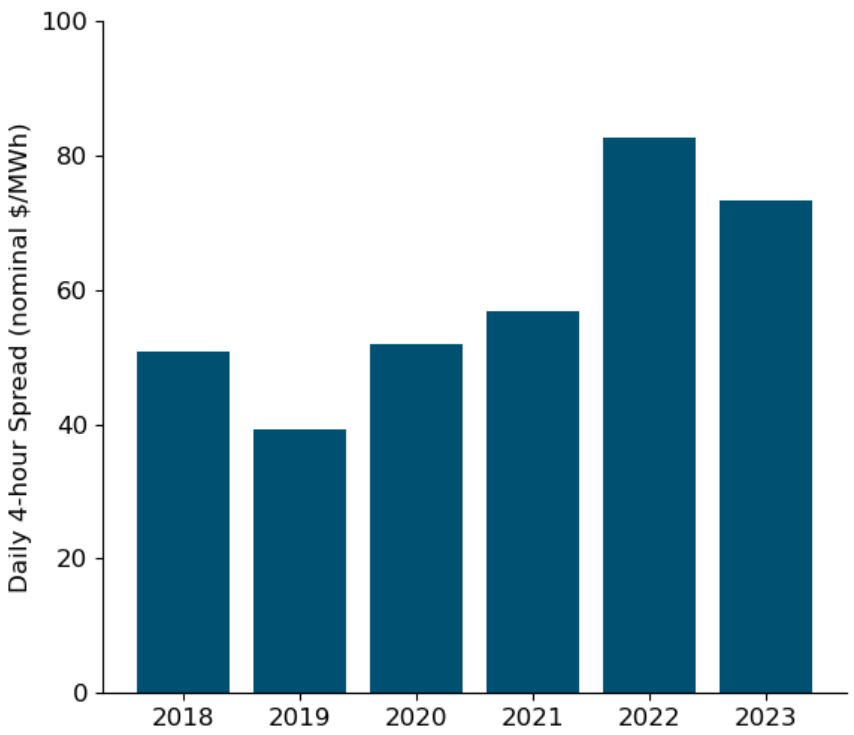


After Years of Regulation-focused Operations, CAISO Batteries are Moving to Majority Energy Arbitrage Operations

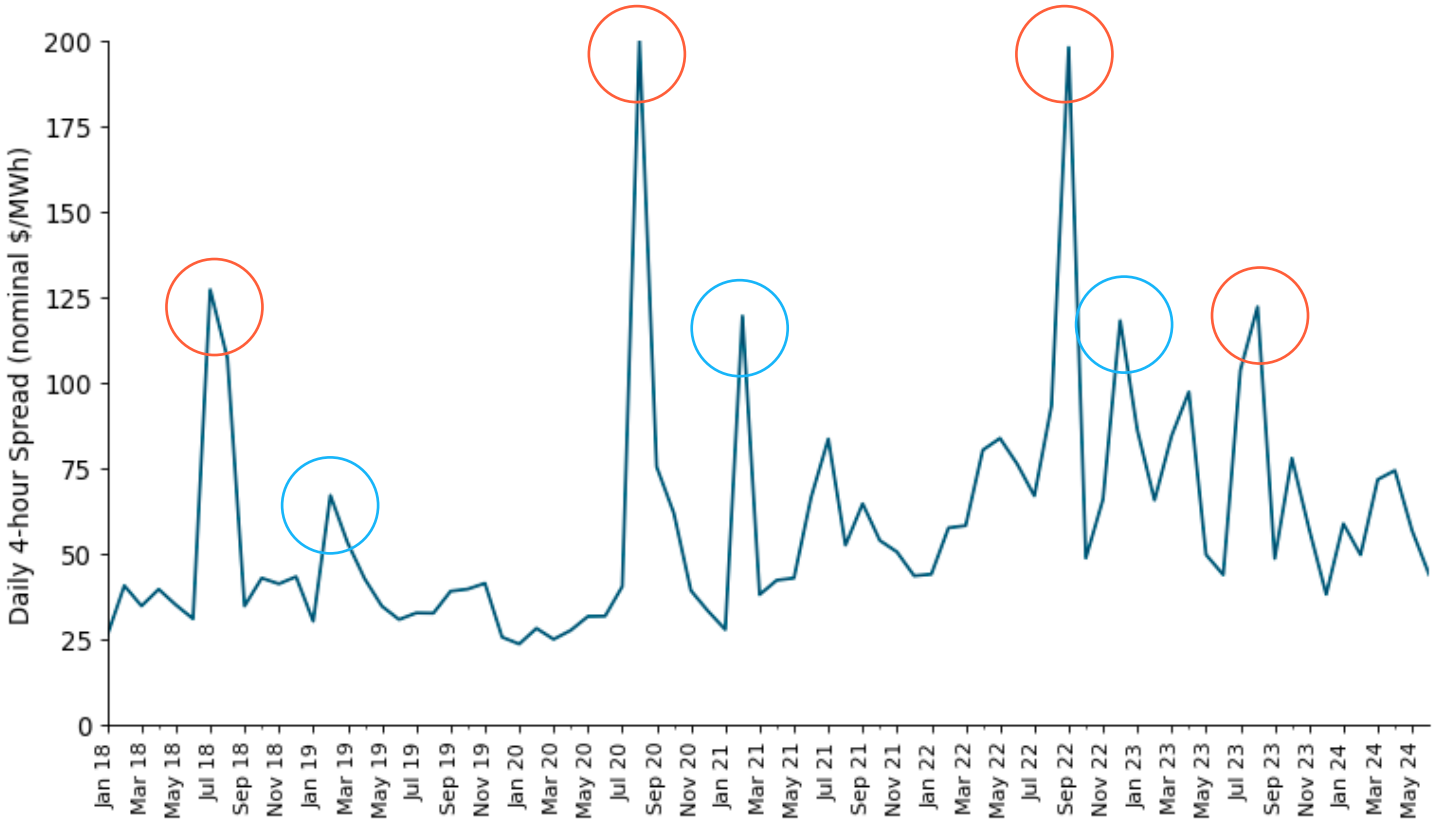


Daily 4-hour Spread of Day-Ahead Energy Prices Represents Arbitrage Opportunities for 4-hour Battery Storage

Annual Average of Daily 4-hour Spread



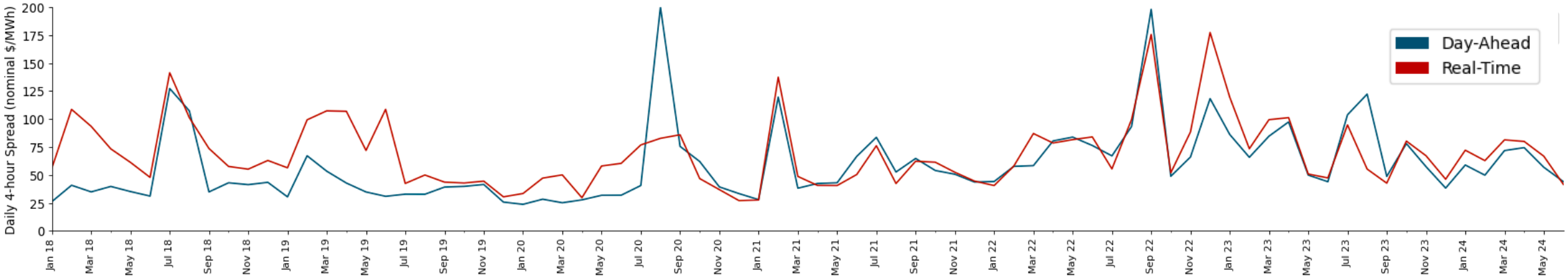
Monthly Averages of CAISO SP15 Daily 4-hour Spread



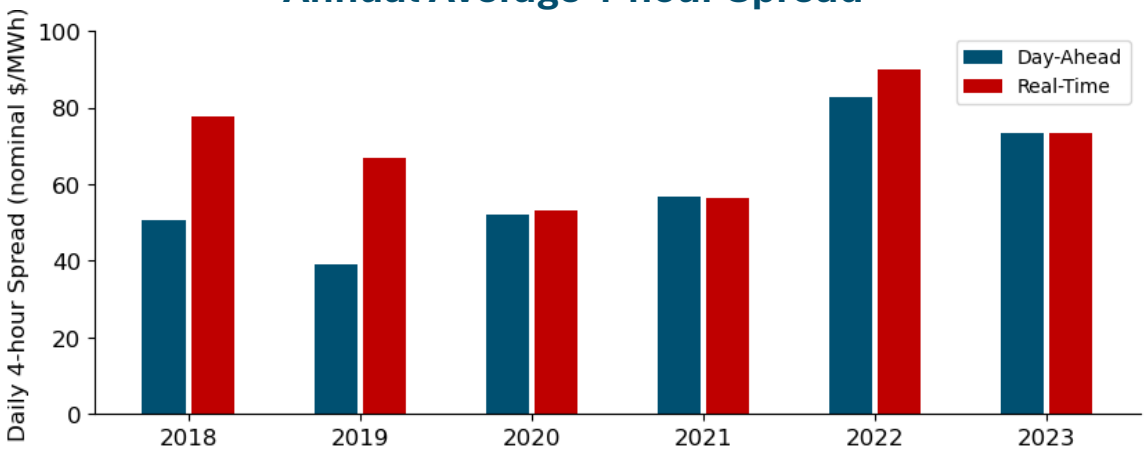
The 4-hour spread is highest in summer months but also peaks in winter months.

Average Spreads in Day Ahead and Real Time Markets are Similar

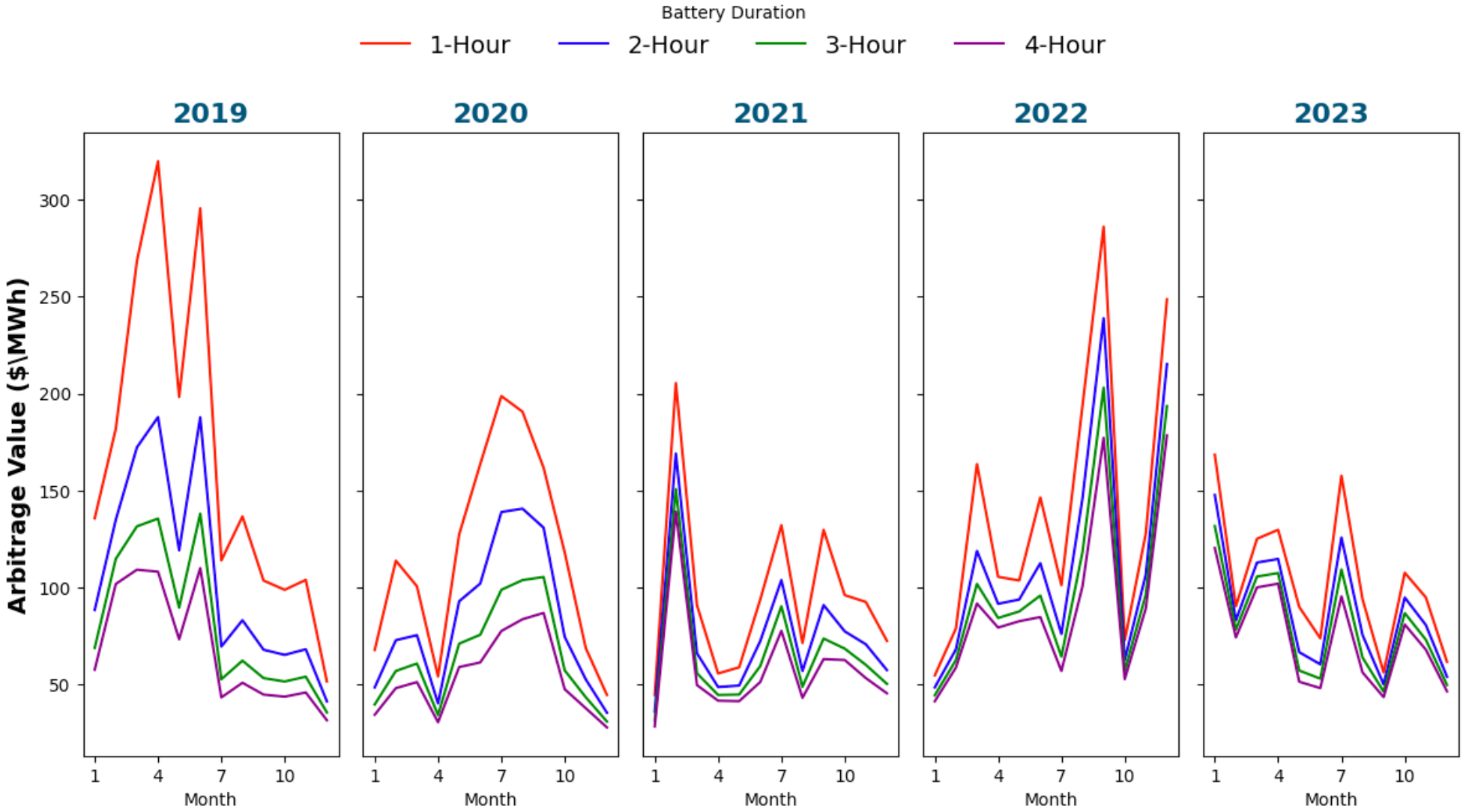
Monthly Average of Daily 4-hour Spread in the SP15 Day-Ahead and 15-min Real-Time Markets



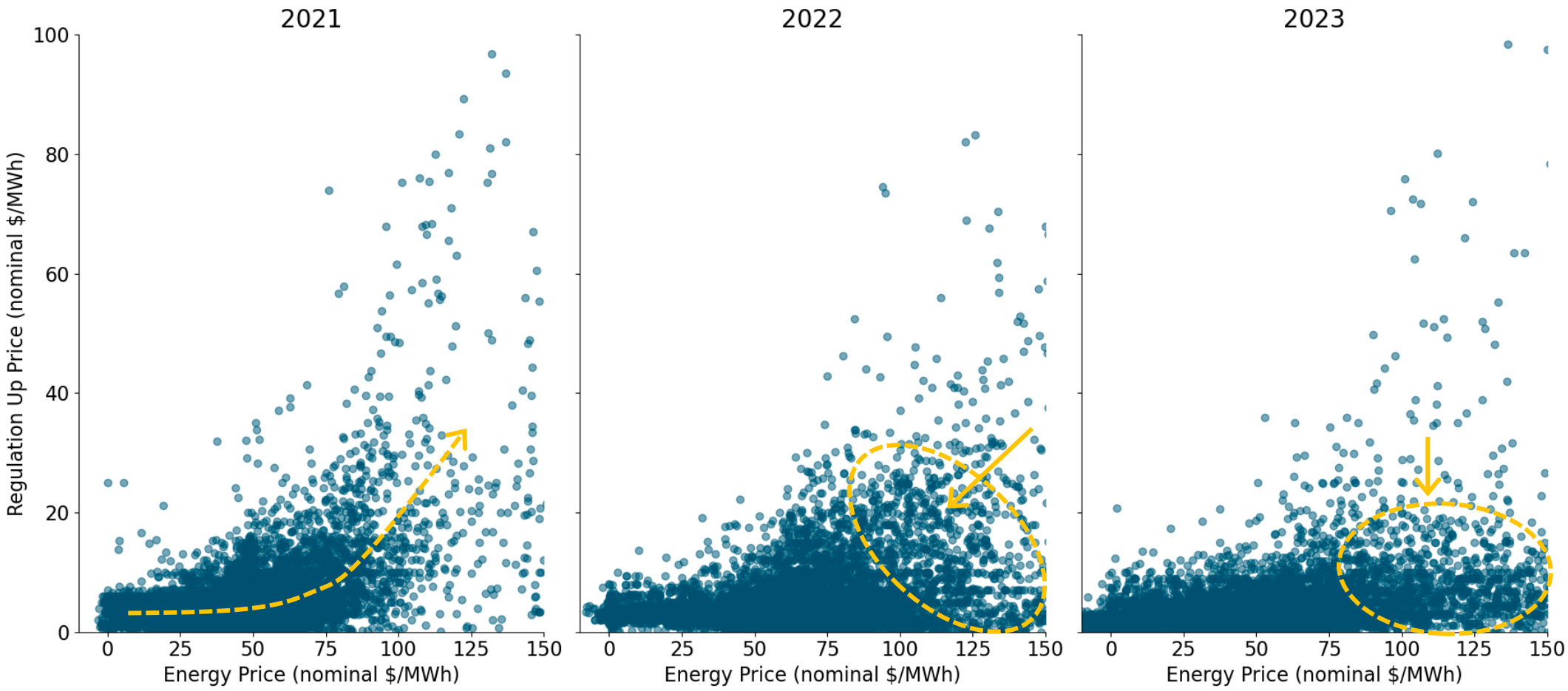
Annual Average 4-hour Spread



5-min Real-Time Energy Arbitrage in CAISO is Trending Down



Ancillary Services Market Prices have Decreased with Increased Battery Storage Builds: Regulation Up



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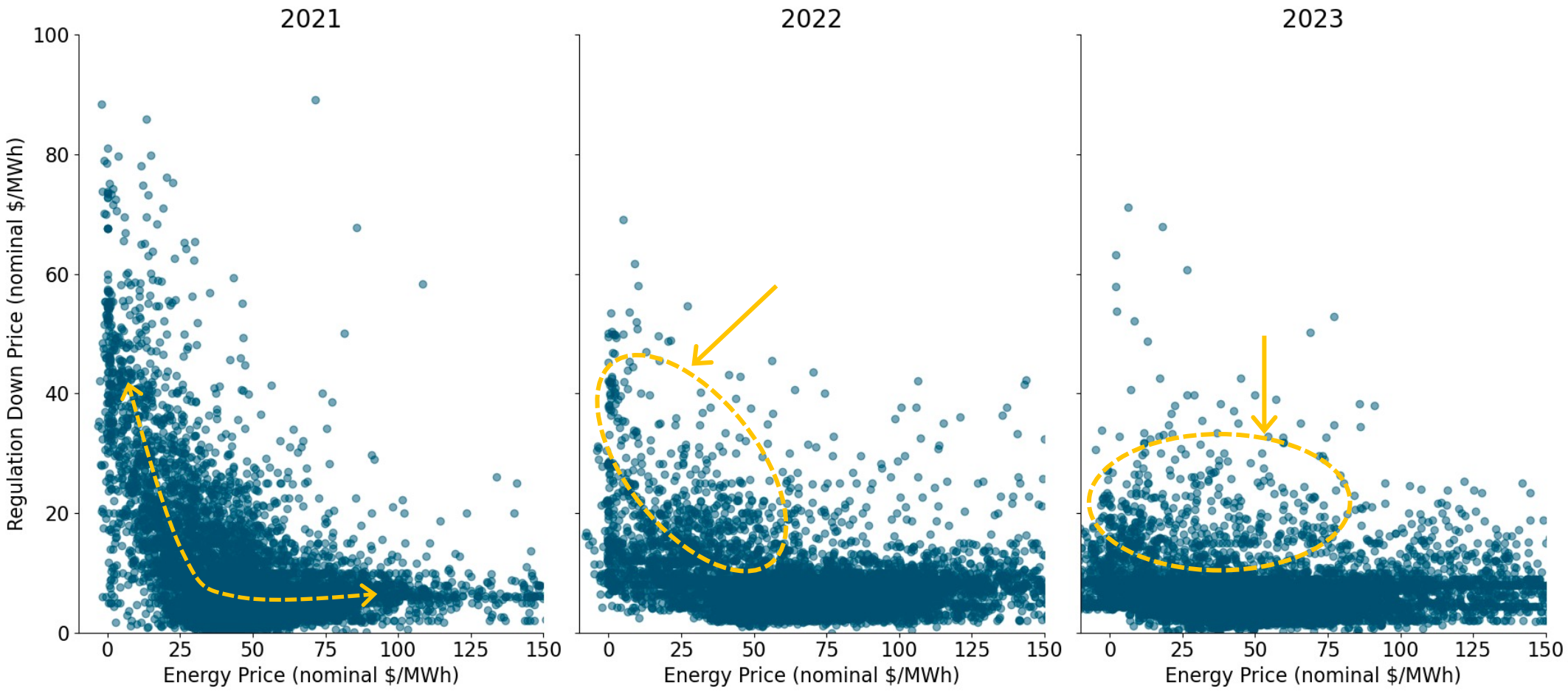
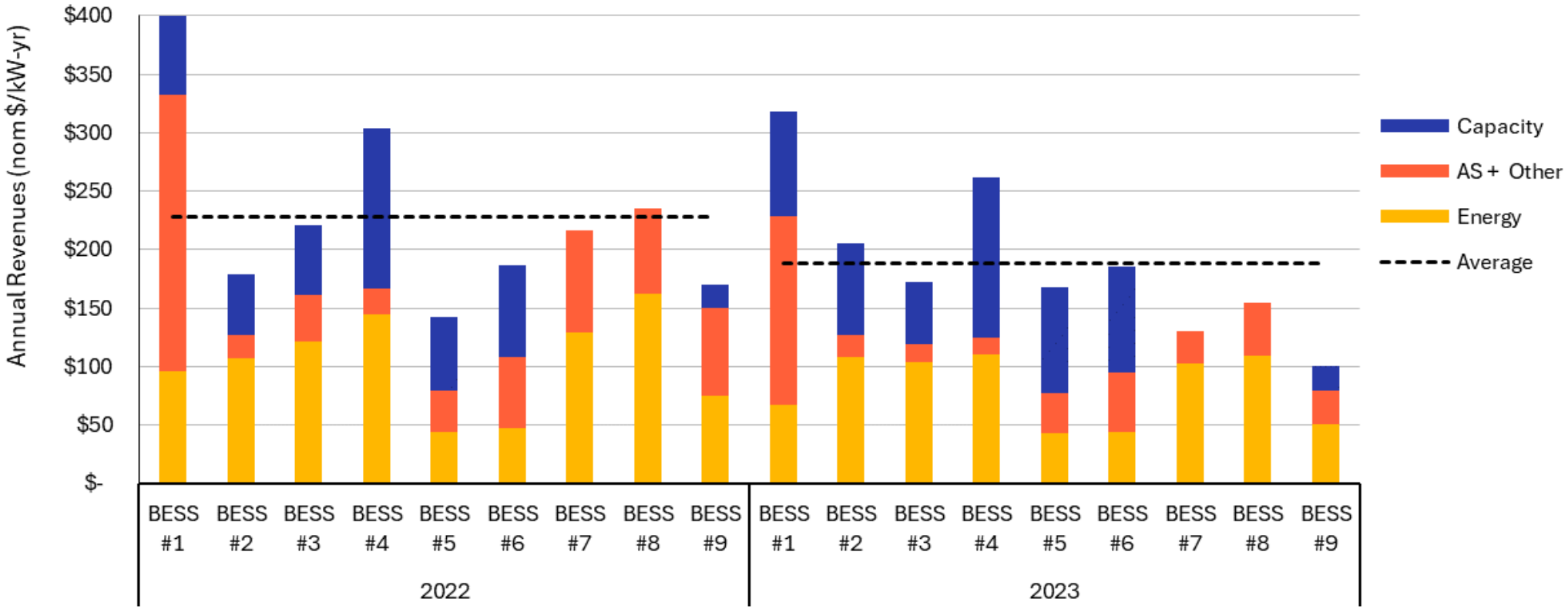


Historical Battery Storage Revenues in CAISO



- Average annual BESS (battery energy storage system) revenues fell from $228 / kW-yr in 2022 to $188 / kW-yr in 2023, primarily driven by lower energy + AS values as gas prices fell and stabilized
- Revenues vary significantly from asset to asset, with a range of 3x ($100 to over $300 / kW-yr) in 2023

Source: FERC EQR Data and E3 analysis.

E3 RESTORE Storage Revenue Forecasting

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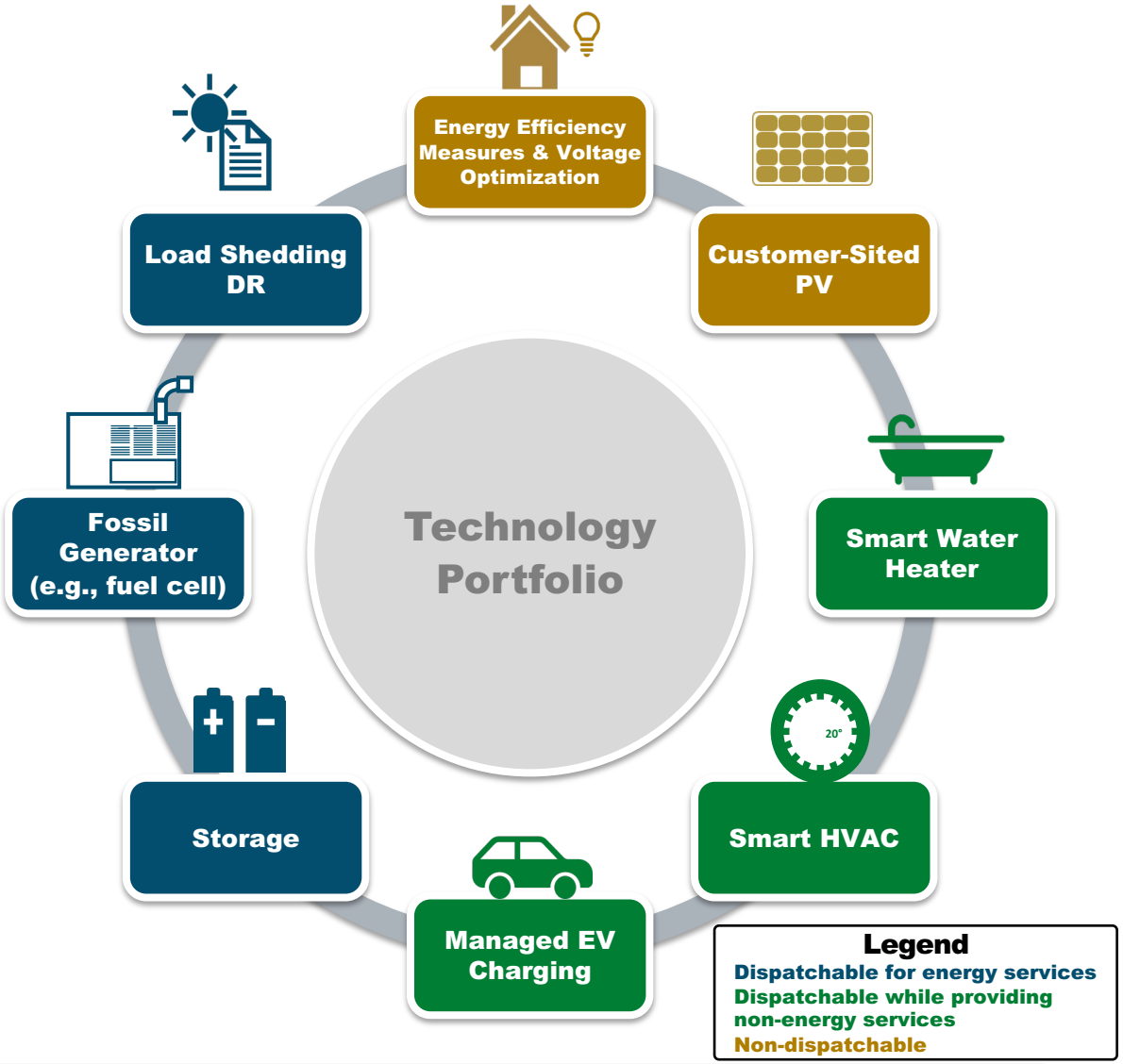
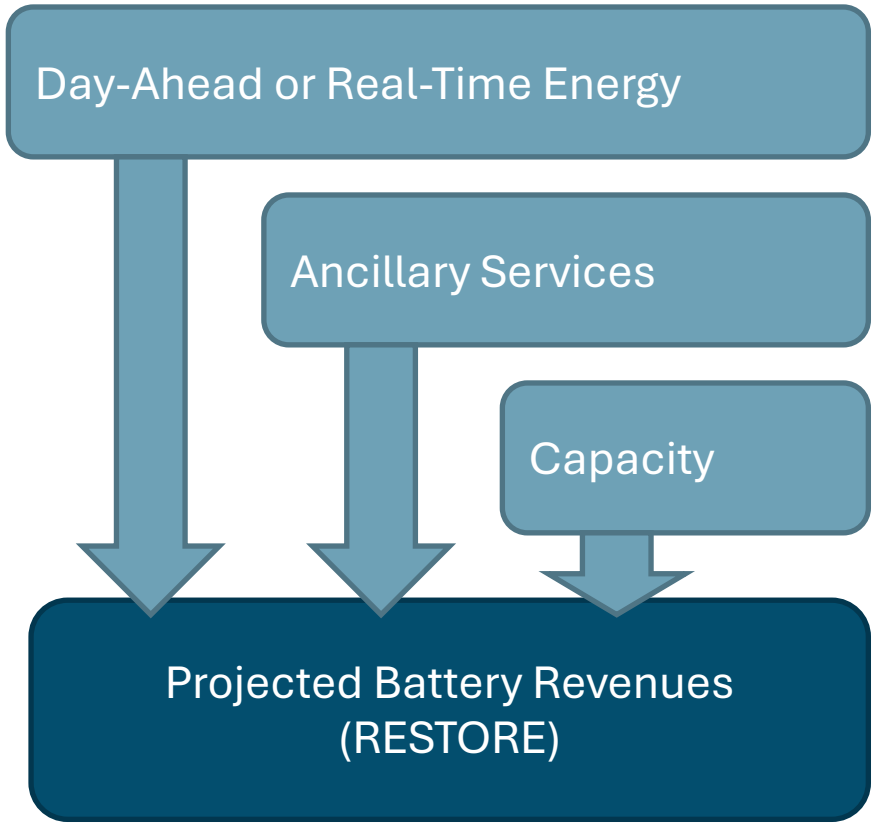
E3 RESTORE Model Introduction

- **RESTORE is a price-taker dispatch optimization model with perfect foresight**
- **RESTORE is capable of modeling many different technologies and customized value streams**
  - Front-of-the-meter storage revenue forecasting is one specific application of the RESTORE model



E3 Storage Revenue Forecasting with RESTORE

- **E3 forecasts battery revenues with RESTORE modeling and realistic expectations of market clearance**
- **Maximizes net revenues of an asset subject to:**
  - Technology operating constraints
    (e.g. round-trip efficiency and cycling limits)
  - Program and market rules
    (e.g. mutually exclusive bid commitment requirements)
- **Capable of co-optimization of multiple technologies (e.g. hybrid or standalone battery storage, combustion turbines, and BTM resources)**



Batteries Seek to Maximize Net Revenues Given Certain Operating Constraints

+ **Power (MW)**
  - Maximum charge and discharge limits
+ **Energy (MWh)**
+ **Cycling limits (Max & Min)**
  - Energy Discharge (including upward reserves)
  - Cycles = energy discharge / energy capacity
+ **Charge and discharge efficiency (%)**
+ **Parasitic losses (%)**
+ **Inverter and interconnection limits (if applicable)**

All storage technical inputs can be changed on an annual basis to reflect degradation and warranty requirements.

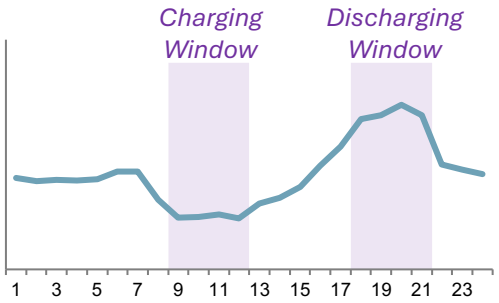
E3 Models Multiple Operational Cases to Produce Final Revenues

i. Day-Ahead Energy Only

Battery optimizes charge and discharge in the day-ahead energy market with perfect foresight of all hourly prices.

ii. Incremental RT Revenues

1 DART Energy Only



i. Day-Ahead Energy + AS

Battery optimizes charge, discharge, and AS in day-ahead market with perfect foresight of all hourly prices.

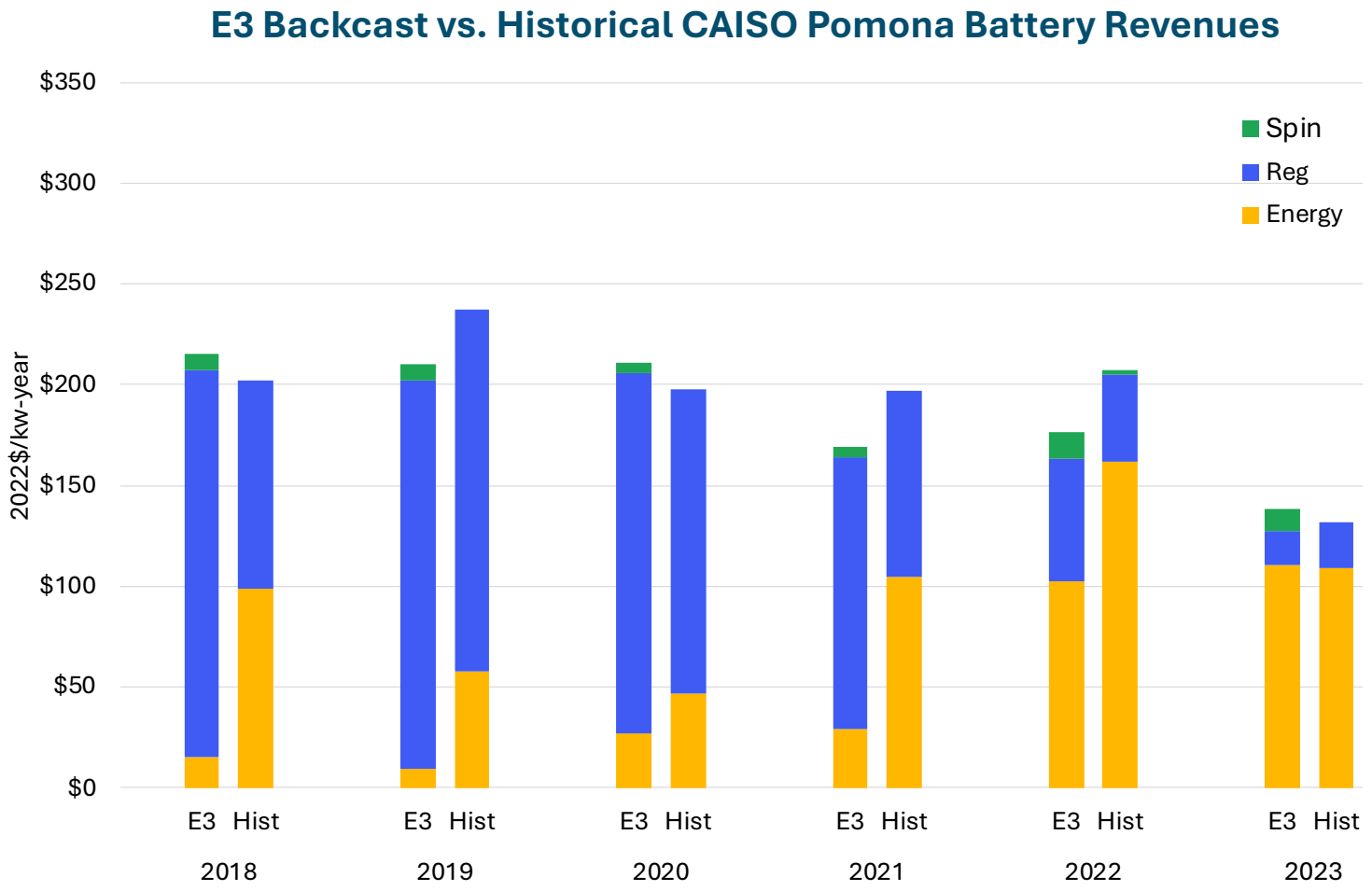
ii. Incremental RT Revenues

2 DART Energy + AS

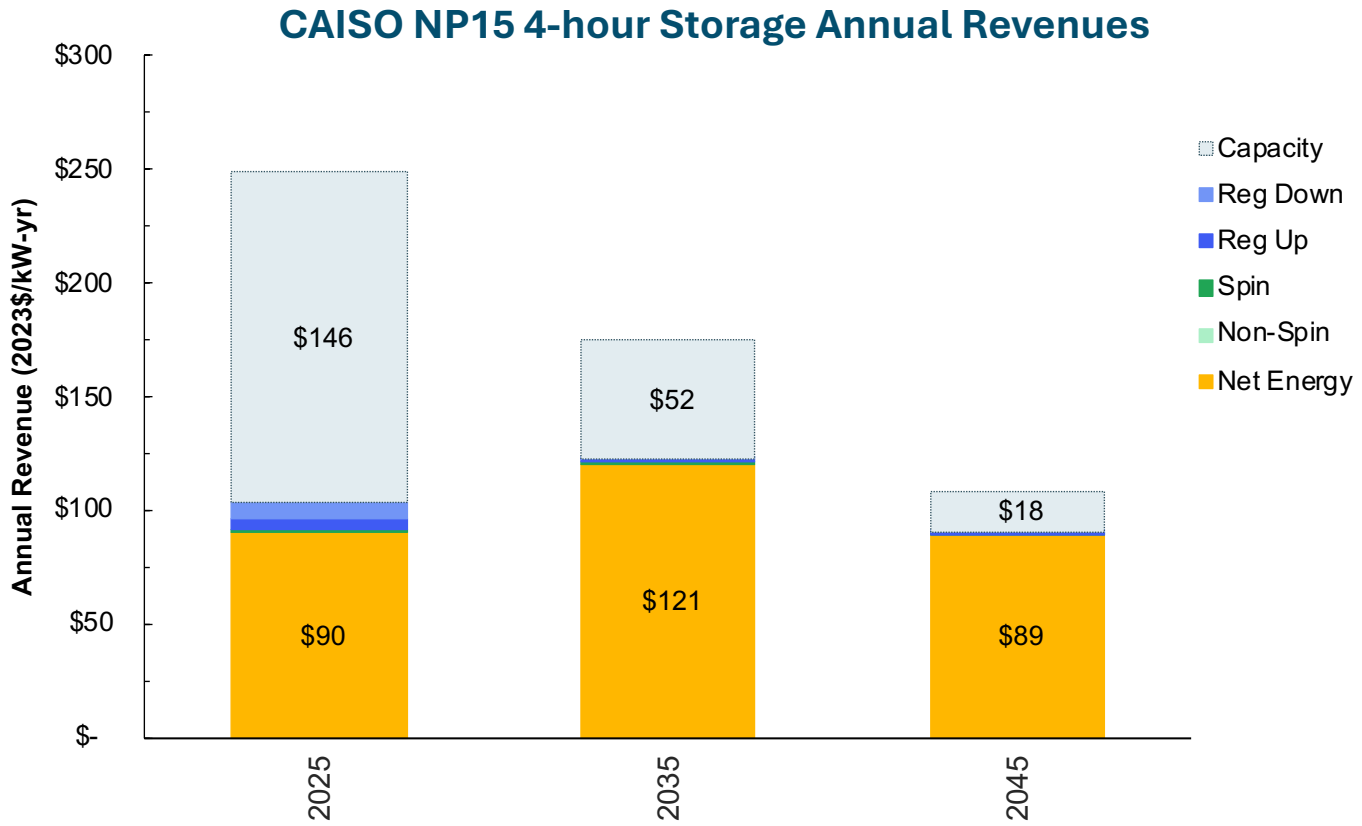
AS Market Clearance Rate Blending

3 **DART Energy + AS Blend "E3 Base Case Revenues"**

E3 Backcast Total Revenues Closely Track Actual Historical Revenues for Pomona Storage Asset



CAISO 4-Hour Storage Earns Higher Proportion of Energy Arbitrage Revenues in Future Years



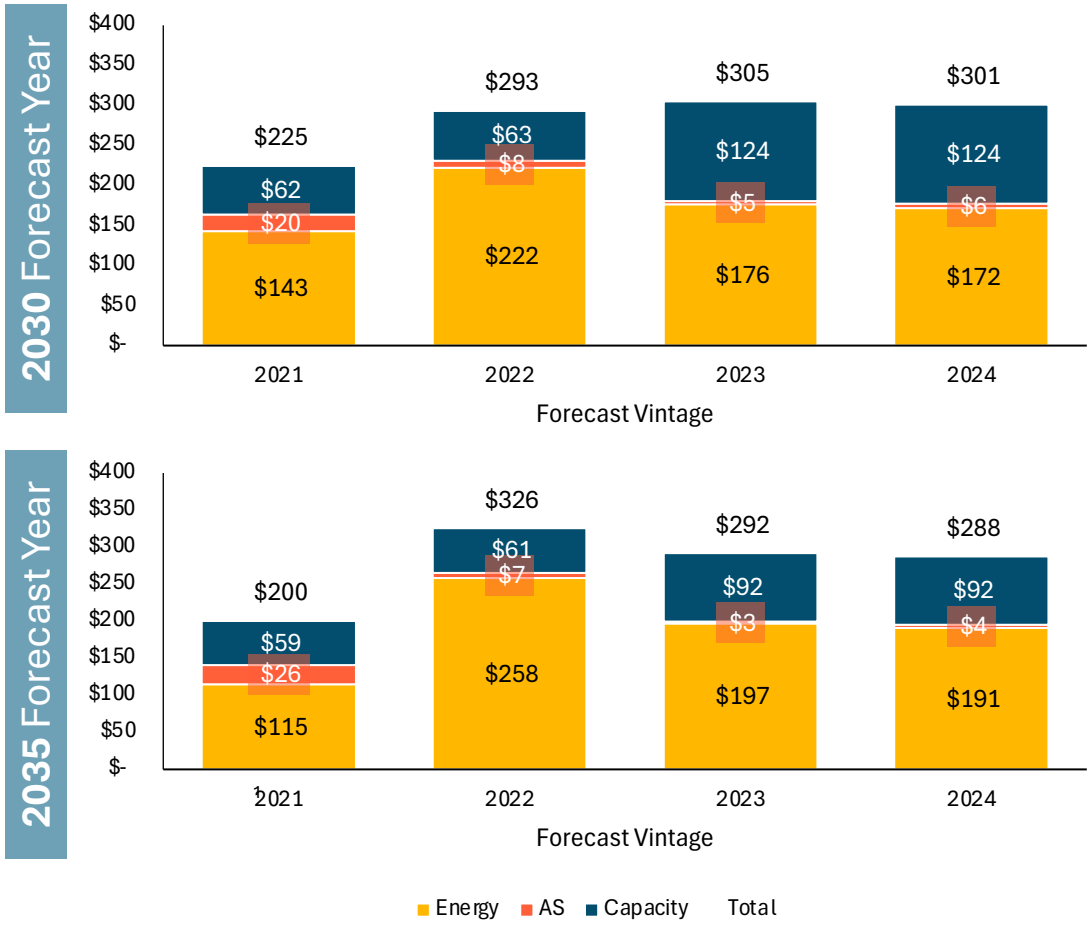
	2025	2035	2045
AS Clearance Rate (%)	23%	16%	10%
Capacity Price ($/kW-mo)	$13.48	$10.79	$10.82
ELCC (%)	90%	40%	14%

A Larger Share of BESS Revenues are Expected to Come From the Capacity / RA Market Instead of the Energy Market

- **Forecasted revenue increased from 2021 vintage[1] to 2022 vintage, reaching ~$300/kW-yr for 2030 and 2035**
- **Since the 2022 vintage, revenue forecasts have remained stable in 2030 and decreased slightly in 2035**
- **Revenue mix has also changed, with capacity revenue taking on increased importance**
  - California Resource Adequacy (RA) prices have increased significantly given both market dynamics and battery net-cost:
    - Mid-Term Reliability Order (MTR) has driven a high demand for battery capacity, which has increased market-wide RA prices
    - AS and energy markets are saturating with increased BESS

CAISO SP15 8-hr. BESS 2030 & 2035 Revenue by Forecast Vintage

($2024/kW-yr)



[1] 2021 data represents synthetic 8-hr. revenue forecast, developed by scaling a 4-hr. energy and AS revenue forecast by average 4-to-8 hr. revenue scaling (~1.7).

Key Takeaways

CAISO energy system supply and demand are rapidly changing which motivates the need for fundamentals-based price and revenue forecasting.

Battery storage market value for capacity, energy, and ancillary services varies widely by asset due to different price dynamics, operational strategies, contractual strategies, and performance which necessitates a flexible and reliable storage revenue forecasting methodology.

Reasonable and trustworthy revenue forecasts aligned with market conditions and trends are important for underwriting investments in storage.

Thank You

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Q&A